<u>We claim:</u>

1. A method of determining an optimum bit load per subchannel in a multicarrier system with forward error correction, comprising:

computing one or more values of a maximum number of symbol errors that can be corrected t, and a number of symbols in the information field K to determine the optimum bit load per subchannel in accordance with the following relationship:

$$1-\left(1-W(s,z,K)\varepsilon_S^{\frac{1}{0.5\cdot sz+1}}\right)^{1/\alpha}$$
$$=\omega\left(b\left(\gamma_{eff},s,z\right)\right)\left(1-2^{-b\left(\gamma_{eff},s,z\right)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b\left(\gamma_{eff},s,z\right)+1}-2\right)}\right), \text{ and}$$
$$\times\left[2-\left(1-2^{-b\left(\gamma_{eff},s,z\right)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b\left(\gamma_{eff},s,z\right)+1}-2\right)}\right)\right]$$

$$W(s,z,K)=\left[\frac{\Gamma(K+s+sz)}{\Gamma(K+s+0.5\cdot sz)\Gamma(0.5\cdot sz+1)}\right]^{-1/(0.5\cdot sz+1)}$$

$$\text{wherein } \omega(b)=\frac{4}{2b+3},$$

$$\Gamma(x)=(x-1)!,$$

s represents a number of discrete-multi-tone symbols in a frame, z represents a number of control code symbols per discrete-multi-tone symbol, b represents a number of bit positions of a quadrature-amplitude-modulation symbol, $\omega(b)$ represents an average fraction of erroneous bits in an erroneous b-sized quadrature-amplitude-modulation symbol, γ_{eff} represents an effective signal-to-noise ratio; and

selecting the maximum number of symbol errors that can be corrected t, and the number of symbols in the information field K such that the uncoded bit error rate p_b that produces a symbol error rate that is less than or equal to the target symbol error rate is increased.

2. The method of claim 1 wherein the effective signal-to-noise ratio γ_{eff} is an average signal-to-noise ratio of at least a subset of the channels.

3. The method of claim 1 wherein the size of the frame ranges from 0 to N_{max}-s-zs symbols.

4. The method of claim 1 further comprising:

determining a difference Θ between a bit error rate prior to decoding and the target bit error rate (p_e) in accordance with the following relationship:

$$\Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e, \text{ and}$$

$$\omega(b(\gamma_{eff}, s, z))p_{QAM}$$
$$= \omega\left(\frac{\alpha}{sn_{eff}}(K+s+zs)\right)\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+s+zs)}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10} \Big/ \left(2^{\frac{\alpha}{sn_{eff}}(K+s+zs)+1}-2\right)}\right)$$
$$\times\left[2-\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+s+zs)}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10} \Big/ \left(2^{\frac{\alpha}{sn_{eff}}(K+s+zs)+1}-2\right)}\right)\right]$$

wherein p_{QAM} represents a probability of error in transmitting a quadrature-amplitude-modulation waveform representing a 2^b point constellation, and p_e represents a channel symbol error rate; and

comparing the value of $\Theta(0)$ and $\Theta(N_{max}\text{-}s\text{-}zs)$ to 0; and

setting the value of K to a predetermined value in response to the comparing.

5. The method of claim 4 wherein when $\Theta(0)<0$ and $\Theta(N_{max}\text{-}s\text{-}sz)<0$, setting $K=N_{max}\text{-}s\text{-}zs$.

6. The method of claim 1 further comprising setting $b(\gamma_{eff}, s, z)$equal to

$$\frac{\alpha\ N_{\max}}{s\ n_{eff}}.$$

7. The method of claim 1 wherein when $\Theta(0)>0$ and $\Theta(N_{max}\text{-}s\text{-}sz)>0$, setting $K=N_{max}\text{-}1$.

8. The method of claim 7 further comprising setting $b(\gamma_{eff}, s, z)$ equal to $b(\gamma_{eff}, 1, 0)$.

9. A method of selecting forward error correction parameters in a channel having a plurality of subchannels in a multicarrier communications system, comprising:

determining a signal-to-noise ratio representing a subset of the subchannels to provide said representative performance measurement;

storing, in a table, the number (s) of discrete multi-tone symbols in a forward-error-correction frame, the number (z) of forward-error-correction control symbols in the discrete multitone symbol associated with the signal-to-noise ratio, and the number of subchannels associated with the signal-to-noise ratio, and a net coding gain for different values of s, z, signal-to-noise ratios and numbers of subchannels; and

selecting forward error correction parameters of the channel based on the net coding gain by applying an approximation to a subset of values in the table.

10. The method of claim 9 wherein the approximation is a bilinear approximation.

11. A method of selecting forward error correction parameters in a channel having a plurality of subchannels in a multicarrier communications system, comprising:

determining a signal-to-noise ratio representing a subset of the subchannels to provide said representative performance measurement;

storing, in a table, the number (s) of discrete multi-tone symbols in a forward-error-correction frame, the number (z) of forward-error-correction control symbols in the discrete multitone symbol associated with the signal-to-noise ratio, the maximum number of transmissions (k) and the number of subchannels associated with the signal-to-noise ratio, and a net coding gain for different values of s, z, signal-to-noise ratios and numbers of subchannels; and

selecting forward error correction parameters of the channel based on the net coding gain by applying an approximation to a subset of values in the table.

12. The method of claim 11 wherein the approximation is a bilinear approximation.

13. The method of claim 11 wherein and the values of s and z are in accordance with the G.dmt standard.

14. The method of claim 13 wherein the values of s and z are in accordance with the G.lite standard, such that a subset of the tables associated with the values of s and z in accordance with the G.dmt standard are used when the channel uses the G.lite standard.

15. A method of increasing a bit load of a multicarrier system comprising a channel having a plurality of subchannels, comprising:

determining a bit load for at least one subchannel based on a target symbol error rate ε_s, a maximum number of symbol errors that can be corrected t, a number of symbols in an information field K, and a maximum number of transmissions k, and a number of bits per subchannel; and

selecting the maximum number of symbol errors t, the number of symbols in the information field K and the maximum number of transmissions k, such that a net coding gain is increased, and wherein t, K and k are also selected such that no forward error correction is applied when the number of subchannels exceeds a predetermined threshold number of subchannels.

16. The method of claim 15 wherein the channel uses the G.dmt standard.

17. The method of claim 15 wherein the channel uses the G.lite standard.

18. A method of determining an optimum bit load per subchannel in a multicarrier system with forward error correction, comprising:

computing one or more values of a maximum number of symbol errors that can be corrected t, and a number of symbols in the information field K to determine the optimum bit load per subchannel in accordance with the following relationship:

$$
\begin{aligned}
&1-\left(1-W(s,z,K)\varepsilon_S^{\frac{1}{0.5\cdot sz+1}}\right)^{1/\alpha} \\
&=\omega(b(\gamma_{eff},s,z))\left(1-2^{-b(\gamma_{eff},s,z)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b(\gamma_{eff},s,z)+1}-2\right)}\right), \text{ and} \\
&\times\left[2-\left(1-2^{-b(\gamma_{eff},s,z)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b(\gamma_{eff},s,z)+1}-2\right)}\right)\right]
\end{aligned}
$$

$$W(s,z,K)=\left[\frac{\Gamma(K+\rho s+sz)}{\Gamma(K+\rho s+0.5\cdot sz)\Gamma(0.5\cdot sz+1)}\right]^{-1/(0.5\cdot sz+1)}$$

$$\text{wherein } \omega(b)=\frac{4}{2b+3},$$

$$\Gamma(\mathrm{x})=(\mathrm{x}-1)!,$$

s represents a number of discrete-multi-tone symbols in a frame, z represents a number of control code symbols per discrete-multi-tone symbol, b represents a number of bit positions of a quadrature-amplitude-modulation symbol, $\omega(b)$ represents an average fraction of erroneous bits in an erroneous b-sized quadrature-amplitude-modulation symbol, γ_{eff} represents an effective signal-to-noise ratio, and ρ represents a number of overhead symbols per discrete multi-tone symbol; and

selecting the maximum number of symbol errors that can be corrected t, and the number of symbols in the information field K such that the uncoded bit error rate p_b that produces a symbol error rate that is less than or equal to the target symbol error rate is increased.

19. The method of claim 18 wherein the effective signal-to-noise ratio γ_{eff} is an average signal-to-noise ratio of at least a subset of the channels.

20. The method of claim 18 wherein the size of the frame ranges from 0 to N_{max}-ρs-sz symbols.

21. The method of claim 18 further comprising:

determining a difference Θ between a bit error rate prior to decoding and the target bit error rate (p_e) in accordance with the following relationship:

$$\Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e \text{, and}$$

$$\omega(b(\gamma_{eff}, s, z))p_{QAM}$$
$$= \omega\left(\frac{\alpha}{sn_{eff}}(K + \rho s + zs)\right)\left(1 - 2^{-\frac{\alpha}{2sn_{eff}}(K+\rho s+zs)}\right) erfc\left(\sqrt{3 \cdot 10^{\gamma_{eff}/10} / \left(2^{\frac{\alpha}{sn_{eff}}(K+\rho s+zs)+1} - 2\right)}\right)$$
$$\times\left[2 - \left(1 - 2^{-\frac{\alpha}{2sn_{eff}}(K+\rho s+zs)}\right) erfc\left(\sqrt{3 \cdot 10^{\gamma_{eff}/10} / \left(2^{\frac{\alpha}{sn_{eff}}(K+\rho s+zs)+1} - 2\right)}\right)\right]$$

wherein p_{QAM} represents a probability of error in transmitting a quadrature-amplitude-modulation waveform representing a 2^b point constellation, and p_e represents a channel symbol error rate; and

comparing the value of $\Theta(0)$ and $\Theta(N_{max}\text{-}\rho s\text{-}sz)$ to 0; and

setting the value of K to a predetermined value in response to the comparing.

22. The method of claim 18 wherein when $\Theta(0)<0$ and $\Theta(N_{max}\text{-}\rho s\text{-}sz)<0$, setting $K=N_{max}\text{-}\ \rho s\text{-}sz$.

23. The method of claim 22 further comprising setting $b(\gamma_{eff}, s, z)$ equal to

$$\frac{\alpha\ N_{\max}}{s\ n_{eff}}\ .$$

24. The method of claim 18 wherein when $\Theta(0)>0$ and $\Theta(N_{max}\text{-}\rho s\text{-}sz)>0$, setting $K=N_{max}\text{-}\rho$.

25. The method of claim 24 further comprising setting $b(\gamma_{eff}, s, z)$ equal to $b(\gamma_{eff}, 1, 0)$.

26. An apparatus for determining an optimum bit load per subchannel in a multicarrier system with forward error correction, comprising:

means for computing one or more values of a maximum number of symbol errors that can be corrected t, and a number of symbols in the information field K to determine the optimum bit load per subchannel in accordance with the following relationship:

$$1-\left(1-W(s,z,K)\varepsilon_S^{\frac{1}{0.5\cdot sz+1}}\right)^{1/\alpha}$$
$$=\omega\left(b(\gamma_{eff},s,z)\right)\left(1-2^{-b(\gamma_{eff},s,z)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b(\gamma_{eff},s,z)+1}-2\right)}\right)\text{, and}$$
$$\times\left[2-\left(1-2^{-b(\gamma_{eff},s,z)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b(\gamma_{eff},s,z)+1}-2\right)}\right)\right]$$

$$W(s,z,K)=\left[\frac{\Gamma(K+s+sz)}{\Gamma(K+s+0.5\cdot sz)\Gamma(0.5\cdot sz+1)}\right]^{-1/(0.5\,sz+1)}$$

$$\text{wherein } \omega(b)=\frac{4}{2b+3},$$

$$\Gamma(x)=(x-1)!,$$

s represents a number of discrete-multi-tone symbols in a frame, z represents a number of control code symbols per discrete-multi-tone symbol, b represents a number of bit positions of a quadrature-amplitude-modulation symbol, $\omega(b)$ represents an average fraction of erroneous bits in an erroneous b-sized quadrature-amplitude-modulation symbol, γ_{eff} represents an effective signal-to-noise ratio; and

means for selecting the maximum number of symbol errors that can be corrected t, and the number of symbols in the information field K such that the uncoded bit error rate p_b that produces a symbol error rate that is less than or equal to the target symbol error rate is increased.

27. The apparatus of claim 26 wherein the effective signal-to-noise ratio γ_{eff} is an average signal-to-noise ratio of at least a subset of the channels.

28. The apparatus of claim 22 wherein the size of the frame ranges from 0 to N_{max}-s-zs symbols.

29. The apparatus of claim 26 further comprising:

means for determining a difference Θ between a bit error rate prior to decoding and the target bit error rate (p_e) in accordance with the following relationship:

$$\Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e, \text{ and}$$

$$\omega\left(b\left(\gamma_{eff}, s, z\right)\right)p_{QAM}$$
$$= \omega\left(\frac{\alpha}{sn_{eff}}(K+s+zs)\right)\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+s+zs)}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}\Big/\left(2^{\frac{\alpha}{sn_{eff}}(K+s+zs)+1}-2\right)}\right)$$
$$\times\left[2-\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+s+zs)}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}\Big/\left(2^{\frac{\alpha}{sn_{eff}}(K+s+zs)+1}-2\right)}\right)\right]$$

wherein p_{QAM} represents a probability of error in transmitting a quadrature-amplitude-modulation waveform representing a 2^b point constellation, and p_e represents a channel symbol error rate; and

means for comparing the value of $\Theta(0)$ and $\Theta(N_{max}\text{-}s\text{-}zs)$ to 0; and

means for setting the value of K to a predetermined value in response to the comparing.

30. The apparatus of claim 26 wherein when $\Theta(0)<0$ and $\Theta(N_{max}\text{-}s\text{-}sz)<0$, setting $K=N_{max}\text{-}s\text{-}zs$.

31. The apparatus of claim 30 further comprising setting $b(\gamma_{eff}, s, z)$equal to

$$\frac{\alpha\ N_{\max}}{s\ n_{eff}}.$$

32. The apparatus of claim 30 wherein when $\Theta(0)>0$ and $\Theta(N_{max}\text{-}s\text{-}sz)>0$, setting $K=N_{max}\text{-}1$.

33. The apparatus of claim 32 further comprising setting $b(\gamma_{eff}, s, z)$equal to $b(\gamma_{eff}, 1, 0)$.

34. An apparatus for selecting forward error correction parameters in a channel having a plurality of subchannels in a multicarrier communications system, comprising:

means for determining a signal-to-noise ratio representing a subset of the subchannels to provide said representative performance measurement;

means for storing, in a table, the number (s) of discrete multi-tone symbols in a forward-error-correction frame, the number (z) of forward-error-correction control symbols in the discrete multitone symbol associated with the signal-to-noise ratio, and the number of subchannels associated with the signal-to-noise ratio, and a net coding gain for different values of s, z, signal-to-noise ratios and numbers of subchannels; and

means for selecting forward error correction parameters of the channel based on the net coding gain by applying an approximation to a subset of values in the table.

35. The apparatus of claim 34 wherein the approximation is a bilinear approximation.

36. An apparatus for selecting forward error correction parameters in a channel having a plurality of subchannels in a multicarrier communications system, comprising:

means for determining a signal-to-noise ratio representing a subset of the subchannels to provide said representative performance measurement;

means for storing, in a table, the number (s) of discrete multi-tone symbols in a forward-error-correction frame, the number (z) of forward-error-correction control symbols in the discrete multitone symbol associated with the signal-to-noise ratio, the maximum number of transmissions (k) and the number of subchannels associated with the signal-to-noise ratio, and a net coding gain for different values of s, z, signal-to-noise ratios and numbers of subchannels; and

means for selecting forward error correction parameters of the channel based on the net coding gain by applying an approximation to a subset of values in the table.

37. The apparatus of claim 36 wherein the approximation is a bilinear approximation.

38. The apparatus of claim 36 wherein the values of s and z are in accordance with the G.dmt standard.

39. The apparatus of claim 38 wherein the values of s and z are in accordance with the G.lite standard, such that a subset of the tables associated with the values of s and z in accordance with the G.dmt standard are used when the channel uses the G.lite standard.

40. An apparatus for increasing a bit load of a multicarrier system comprising a channel having a plurality of subchannels, comprising:

means for determining a bit load for at least one subchannel based on a target symbol error rate ε_s, a maximum number of symbol errors that can be corrected t, a number of symbols in an information field K, and a maximum number of transmissions k, and a number of bits per subchannel; and

means for selecting the maximum number of symbol errors t, the number of symbols in the information field K and the maximum number of transmissions k, such that a net coding gain is increased wherein the means for also selects t, K and k such that no forward error correction is applied when the number of subchannels exceeds a predetermined threshold number of subchannels.

41. An apparatus for determining an optimum bit load per subchannel in a multicarrier system with forward error correction, comprising:

means for computing one or more values of a maximum number of symbol errors that can be corrected t, and a number of symbols in the information field K to determine the optimum bit load per subchannel in accordance with the following relationship:

$$1-\left(1-W(s,z,K)\varepsilon_S^{\frac{1}{0.5\cdot sz+1}}\right)^{1/\alpha}$$
$$=\omega\left(b\left(\gamma_{eff},s,z\right)\right)\left(1-2^{-b\left(\gamma_{eff},s,z\right)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b\left(\gamma_{eff},s,z\right)+1}-2\right)}\right), \text{ and}$$
$$\times\left[2-\left(1-2^{-b\left(\gamma_{eff},s,z\right)/2}\right)erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{b\left(\gamma_{eff},s,z\right)+1}-2\right)}\right)\right]$$

$$W(s,z,K)=\left[\frac{\Gamma(K+\rho s+sz)}{\Gamma(K+\rho s+0.5\cdot sz)\Gamma(0.5\cdot sz+1)}\right]^{-1/(0.5sz+1)}$$

$$\text{wherein } \omega(b)=\frac{4}{2b+3},$$

$$\Gamma(x)=(x-1)!,$$

s represents a number of discrete-multi-tone symbols in a frame, z represents a number of control code symbols per discrete-multi-tone symbol, *b* represents a number of bit positions of a quadrature-amplitude-modulation symbol, $\omega(b)$ represents an average fraction of erroneous bits in an erroneous *b*-sized quadrature-amplitude-modulation symbol, γ_{eff} represents an effective signal-to-noise ratio, and ρ represents a number of overhead symbols per discrete multi-tone symbol; and

means for selecting the maximum number of symbol errors that can be corrected t, and the number of symbols in the information field K such that the uncoded bit error rate p_b that produces a symbol error rate that is less than or equal to the target symbol error rate is increased.

42. The apparatus of claim 41 wherein the effective signal-to-noise ratio γ_{eff} is an average signal-to-noise ratio of at least a subset of the channels.

43. The apparatus of claim 41 wherein the size of the frame ranges from 0 to N_{max}-ρs-sz symbols.

44. The apparatus of claim 41 further comprising:

means for determining a difference Θ between a bit error rate prior to decoding and the target bit error rate (p_e) in accordance with the following relationship:

$$\Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e,$$

$$\begin{aligned}
&\omega(b(\gamma_{eff}, s, z))p_{QAM} \\
&= \omega\left(\frac{\alpha}{sn_{eff}}(K+\rho s+zs)\right)\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+\rho s+zs)}\right) erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{\frac{\alpha}{sn_{eff}}(K+\rho s+zs)+1}-2\right)}\right) \\
&\quad\times\left[2-\left(1-2^{-\frac{\alpha}{2sn_{eff}}(K+\rho s+zs)}\right) erfc\left(\sqrt{3\cdot 10^{\gamma_{eff}/10}/\left(2^{\frac{\alpha}{sn_{eff}}(K+\rho s+zs)+1}-2\right)}\right)\right]
\end{aligned}$$

wherein p_{QAM} represents a probability of error in transmitting a quadrature-amplitude-modulation waveform representing a 2^b point constellation, and p_e represents a channel symbol error rate;

comparing the value of $\Theta(0)$ and $\Theta(N_{max}\text{-}\rho s\text{-}zs)$ to 0; and setting the value of K to a predetermined value in response to the comparing.

45. The apparatus of claim 41 wherein when $\Theta(0)<0$ and $\Theta(N_{max}\text{-}\rho s\text{-}sz)<0$, setting $K=N_{max}\text{-}\rho s\text{-}zs$.

46. The apparatus of claim 45 further comprising setting $b(\gamma_{eff}, s, z)$equal to

$$\frac{\alpha \; N_{\max}}{s \; n_{eff}}.$$

47. The apparatus of claim 41 wherein when $\Theta(0)>0$ and $\Theta(N_{max}\text{-}\rho s\text{-}sz)>0$, setting $K=N_{max}\text{-}\rho$.

48. The apparatus of claim 47 further comprising setting $b(\gamma_{eff}, s, z)$equal to $b(\gamma_{eff}, 1, 0)$.